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Testing the first-order SOC decay hypothesis over multiple sites through Bayesian uncertainty representation

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The conventional soil organic matter (SOM) decay paradigm considers SOM quality as the dominant decay limitation, and it is modelled with simple first-order decay kinetics. This view and modelling approach is criticized for being too simplistic and unreliable for predictive purposes. It is still under debate if first-order models can correctly capture the variability in temporal SOM decay observed between different environments. The hypothesis needs to be tested statistically, but this implies the use of a dynamic model with multiple degrees of freedom to describe the observations. Since we want to test the general validity of the SOC decay theory the test must also include multiple sites, and rises the problem of how to describe the unavoidable local variability. This defines a multivariate space where the hypothesis must be tested which, considering also the known problem of an equifinality "by design" in biogeochemical models, generate difficulties.

To address this issue, we calibrated a first-order model (Q) on six long-term bare fallow field experiments across Europe within a Bayesian framework assuming some general and some local parameters. Following conventional SOM decay theory, we assumed that parameters directly describing SOC decay (rate of SOM quality change and decomposer metabolism) are thermodynamically constrained, therefore valid for all sites. Initial litter input quality and edaphic interactions (both local by definition) and microbial efficiency (possibly affected by nutrient stoichiometry) were instead assumed to be site-specific. Initial litter input quality explained most observed kinetics variability, and the model predicted a convergence toward a common kinetics over time, while site-specific variables played no detectable role. All these characteristics could be represented with posterior probability distributions and their comparison provided the hypothesis testing.

According to our analysis the decay of decades-old SOM seemed mostly influenced by OM chemistry and was well described by first order kinetics and a single set of general kinetics parameters.